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Lubrication

A Technical Publication Devoted to
the Selection and Use of Lubricants

THIS ISSUE

Measured Lubrication

PUBLISHED BY
THE TEXAS COMPANY
TEXACO PETROLEUM PRODUCTS

Why . . .
MEASURED LUBRICATION

MEASURED LUBRICATION (as opposed to hit or miss, "trusting that it will work right" form of lubrication) provides the plant operator with a means of controlling those factors, which, without control would seriously impair the behavior of the lubricant applied, and ultimately, the function of the machinery itself.

The factors that Measured Lubrication will control are:

1. The formation of carbon.
2. The application of lubricants to insure the maximum efficiency.
3. The amount of oil entering exhaust (a very important point in the lubrication of steam engines).

The purpose of the article on Measured Lubrication in this issue is to elucidate why the control of lubrication is important. It is our belief that this article's explanation of the effect of Measured Lubrication upon the control of carbon alone will be of value to all who are in charge of machinery operation.

Since the mechanical lubricator was introduced The Texas Company has cooperated to the fullest extent in determining the amounts and types of lubricants best suited to bring about the most effective and economical performance of this modern appliance. Somewhere in The Texas Company's complete line of lubricants there is one that is best for you.

If you are interested in Measured Lubrication—if you are interested in increasing the effectiveness of the mechanical lubricating systems under your supervision—do not hesitate to ask us any further questions which the ensuing article may provoke.

THE TEXAS COMPANY
Texaco Petroleum Products

LUBRICATION

A Technical Publication Devoted to the Selection and Use of Lubricants

Published by

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Vol. XVIII March, 1932 No. 3

Measured Lubrication

DETERMINATION of the lubricating requirements of any piece of machinery is a fascinating study, for it entails not only knowledge of machine design, but also familiarity with operating conditions, along with an understanding of the lubricant characteristics and methods of application. If carried out in an intelligent manner certain very definite results are attainable, of which reduced maintenance costs, maximum production, and insurance of positive functioning of machinery are outstanding. It is, therefore, an economic necessity to investigate the duty to which any lubricant may be subjected, and the benefits to accrue from its proper application.

Of distinct interest is the question of measured lubrication. The necessity for definite control of the supply of lubricant in the case of cylinders, as involved in the steam engine, air compressor and refrigerating machine was recognized early in the study of lubrication as related to machine design. Later developments have indicated that similar control in connection with certain types of bearing construction is of material advantage, even though it may mean operation on the all-loss principle. Until today the mechanical force feed lubricator, along with the utilization of centralized pressure, has become extensively adopted where positive lubrication, economy, cleanliness and insurance against accumulation of non-lubricating matter around moving parts are essential.

Power plant and mass production machinery require careful consideration in this regard. Mass production is distinctly a matter of perfect synchronization of machine operations. Obviously it would fail were any unit to become inoperative or function out of tune with respect to those adjacent. In the interest of assured continuity of production, it is the duty of the operators to guard against impending trouble rather than to control the actual operations of their respective machines. In this connection, they are materially aided by the use of automatic lubrication, whereby the human factor in actual application is eliminated as far as possible.

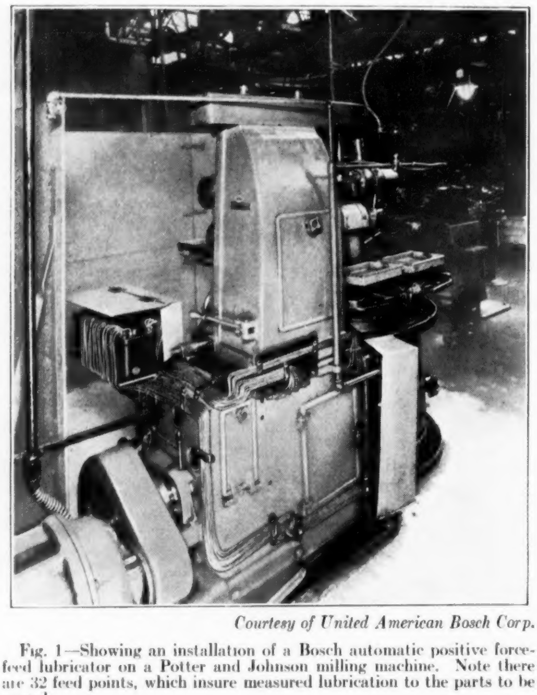
The trend towards automatic lubrication of machinery, pertinent to mass production, whether it involves automobiles, ice cream or coal, has been a natural sequence to the development of such machinery, for dependability in operation can be directly measured by the degree to which wear is prevented and friction reduced. So, manual methods of lubrication soon proved to be inadequate. Furthermore, they presented a certain amount of hazard which increased in proportion to speed, or the relative location of the parts to be lubricated. Hence the adoption of the mechanical force feed lubricator and centralized pressure.

THE MECHANICAL FORCE FEED LUBRICATOR

With this device not only is one-time lubrication involved, but furthermore, oil is delivered in as nearly as possible the requisite amount to meet the actual requirements of the moving parts. With due care when installing and proper adjustment of the rate of oil feed, such lubricators are dependable and decidedly economical.

There is a further advantage in that by virtue of the fact that such lubricators can be readily

driven by the machinery which they serve, they can be made to function only when the latter is in operation, and then only at a proportional speed. In other words, the higher the speed of operation, the more oil will be delivered. The pumping capacity and rate of oil flow is therefore variable. As a result, such a lubricator will automatically start or stop with the machine to which it is attached.



Courtesy of United American Bosch Corp.

Fig. 1—Showing an installation of a Bosch automatic positive force-feed lubricator on a Potter and Johnson milling machine. Note there are 32 feed points, which insure measured lubrication to the parts to be served.

Equipment of this nature has been very successfully applied to a wide variety of machinery where it is practicable to drive the lubricator by direct connection from some external moving part. This can be brought about by a link mechanism, an eccentric located on some rotating element, through belt connection from the machine itself, or by the use of an electric motor and speed reduction mechanism.

There is more or less of a limitation, however, involved in the use of a mechanical force feed lubricator for certain types of large machines, in that the capacity is oftentimes comparatively small in contrast with a flood circulating system, hence requiring more frequent filling. On the other hand, this will depend upon the extent of operation, the number of oil feeds and the rate of delivery. This latter must be worked out in actual practice, according to the requirements of the parts to be lubricated and the nature of the oil being used.

Relation of Operating Pressures

In the selection of virtually any means of pressure lubrication, it is important to have at least an approximate idea as to the operating pressures which will prevail between the moving elements. This is especially true in the case of mechanical force feed oilers. Where circulating flood lubrication is involved, volume in company with pump pressure can be depended upon to maintain the necessary lubricating film between the wearing elements. With the mechanical force feed oiler, on the other hand, pressure alone is involved, for as already mentioned, the principle of operation is to deliver oil in as nearly as possible the right amount to maintain effective lubrication and economical operation.

As a result, pump pressure should not vary to any wide degree, nor should the lubricator be allowed to run dry, otherwise lubrication would cease in a comparatively short time.

It is interesting to note, in this regard, that where desirable a central source of supply can be employed. In other words, it is practicable to reduce the labor of filling by bringing this about through a suitable filling line, run from the main supply tank. It is also practicable to install a steam heating coil in the bottom of such a lubricator.

In certain installations this latter will be a decided advantage, especially where machines may be exposed to low atmospheric temperatures. In such cases means for preheating the oil prior to delivery will be desirable, otherwise it might easily become so sluggish as to cease to flow through the pumping elements or feed lines. This would be especially true where comparatively high viscosity cylinder oils are involved.

CENTRALIZED PRESSURE LUBRICATION

Another interesting phase in connection with pressure lubrication has been the development of a means of centralized lubrication which functions by virtue of a central control, all wearing parts so served being periodically flushed and supplied automatically with oil from a central reservoir. By locating this latter adjacent to the machine to be lubricated and within ready reach of the operator and equipping it with a suitable plunger which operates the pump, lubrication of all parts connected thereto becomes but a matter of pressing a button, pulling the plunger, or turning a wheel whenever necessary or recommended by the builders, according to the operating conditions involved. In such a system the amount of lubricant fed is restricted to as nearly as possible the theoretical lubricating requirements of the respective bearings.

The fact that certain bearings will vary from others in regard to their requirements renders it necessary to provide for some arrangement of regulation or control of flow. Practically, this amounts to a metering of the lubricant in terms of drops. It can be brought about either by proper individual construction of the drip plugs, which on such equipment are also known as control outlets; by use of a control device located at the base of the pump, or by the installation of suitable adjusting manifolds at salient points in the system.

Properly installed, such systems are claimed to be relatively fool-proof, exceedingly simple to operate, and an insurance that clean oil will be delivered to the respective bearings. It is essential, however, that all parts be of rigid construction and capable of withstanding jars, shocks and temperature fluctuations, for while piping, etc., is guarded wherever possible it is relatively impossible to protect all parts absolutely from the chance of contact with external materials.

It is interesting to note that the possibility of entry of dust into such a system is quite as negligible as in a pressure grease lubricator. Further to insure that clean oil is used, a suitable filtering media, such as a felt pad or screen is employed, which will normally effectively remove any foreign matter that may have entered the oil in the course of storage or handling prior to usage; although lubricating oils as received from, or delivered by, reputable oil refiners can be relied upon as being free from foreign matter.

Pulsating Control

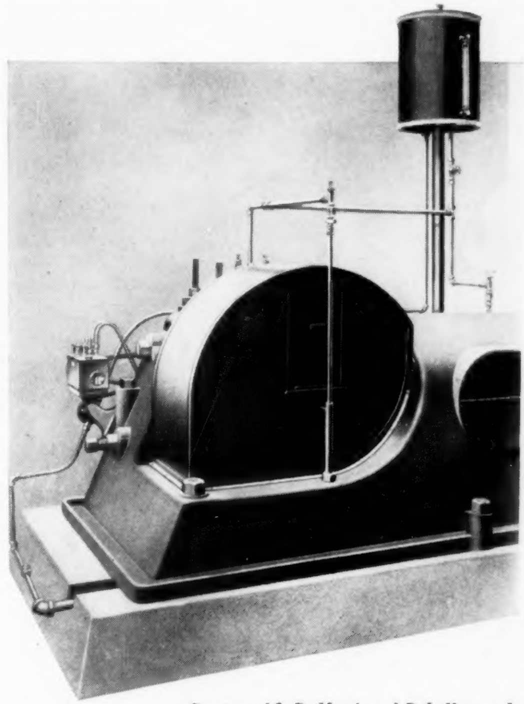
By use of the principles of pulsation and a suitable pressure control valve to regulate the oil flow, the necessity for manual operation, however, can be done away with. The lubricator itself is driven by belt or gear connection from any rotating part of the machine to be served. This is a decided adjunct where an extensive number of bearings are to be served, for the entirely automatic feature eliminates the possible factor of human error, the only alteration required occurs when the oil reservoir is to be filled, or any individual feeder adjusted.

In such a system the oil is fed only during a pulsation or high pressure period in the cycle of pump operation, control being maintained by a suitable plate valve arrangement. An added feature is the practicability of flushing the entire system under the prevailing pressure at the high pressure period, by pressing down a suitable flushing button which is a part of the pump unit.

STEAM CYLINDER LUBRICATION

Steam cylinder lubrication, as perhaps the outstanding example of measured lubrication, will require more detailed consideration of actual operating conditions than any other phase of general plant lubrication. Yet, the potential problems which may result will not usually be difficult of solution, provided that the conditions to which the oil may be subject are thoroughly analyzed, and the workings of the mechanical force feed lubricator properly understood.

The several operating conditions which may affect the performance of a steam cylinder oil, and govern the rate of delivery by the lubricator involve: steam pressure, temperature, velocity, moisture in the steam, degree of superheat, priming or foaming, point of introduction, boiler compounds and, the use (if any) which is to be made of the exhaust steam.



Courtesy of I. P. Morris and DeLaVergne, Inc.

Fig. 2—Showing an oil filter, pump and the distribution piping for a high speed compressor. Note in particular the manner of installation of the lubricator and the sight feed control elements.

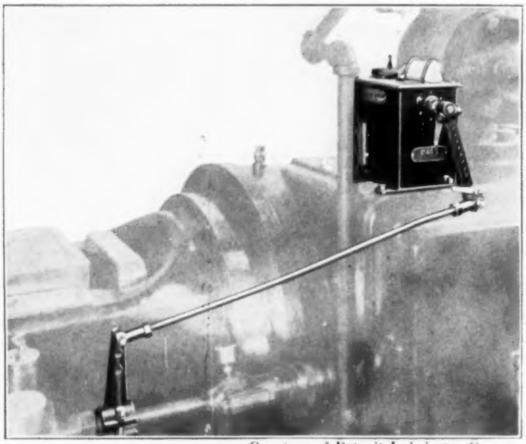
Pressure and Temperature

While steam pressure alone will have but little influence upon a cylinder oil, the temperature associated with the pressure, as well as the degree of superheat to which the steam may be subject, has a very marked effect.

The usual operating temperatures in the steam cylinder and valve chest must be taken into consideration when selecting any cylinder oil, due to the effect which they may have upon the viscosity of the oil film on the cylinder walls and valve seat. In other words, viscosity will be decreased accordingly as steam temperatures

are increased. Therefore, where operating with high temperature saturated or superheated steam a heavier bodied oil should be used, or else the flow of lighter lubricant increased sufficiently to compensate for its lesser viscosity.

Conversely where steam pressures are low, or where a partial vacuum with accompanying low temperatures exist, a more easily atomized oil is necessary. This should be either a filtered product or a lower viscosity oil.



Courtesy of Detroit Lubricator Company

Fig. 3—Showing the manner of installation of a force-feed lubricator on a steam engine, and means for driving same.

The effect of higher temperatures upon the actual chemical behavior of the oil in the engine will normally be negligible. For example, the "operating temperature" for saturated steam at even 600 pounds will be but 486.6 degrees Fahr. This is below the open flash point of any cylinder oil. Furthermore, it is probable that the flash point would be raised with the increased pressure. As a result, there does not seem to be any reason for the common belief that a very high flash or fire test is necessary. Saturated steam always contains moisture and as there is no free oxygen present in the steam it does not seem likely that a flash could be produced in the cylinder regardless of the flash point of the oil.

Temperature and Velocity Improve Atomization

Steam temperature and velocity, however, affect the atomization of the cylinder oil to a marked extent. Thus, the higher the temperature and velocity the more readily will a heavy bodied oil be atomized, due to the reduction in viscosity which occurs at the temperature of operation.

Moisture

From the viewpoint of the actual composition of a cylinder oil, the question of moisture in the steam is the most important factor involved. Steam will always contain a certain percentage of moisture unless it is superheated to a sufficient extent to counteract any line and cylinder condensation, which may be caused by the cooling effect of the piping or cylinder walls and the expenditure of heat by the expansion stroke. The presence of moisture in steam will usually result in a film of straight mineral lubricating oil being rapidly washed off from the cylinder walls and other surfaces with which the steam comes in contact. Therefore, to secure proper lubrication under wet steam conditions it is necessary to either increase the rate of flow of the straight mineral oil, or else substitute an oil which contains a certain percentage of fatty compound such as lard oil, degras or tallow. Obviously the latter is most advisable in the interest of economy.

The practice of using a straight mineral oil to lubricate wet steam is customary only where the presence of a fatty oil in the exhaust steam is objectionable. The increased amount necessary to insure proper lubrication will often result in imperfect atomization. As a consquence, oil accumulation in the cylinder will be prevalent and carbon deposits developed.

Especially will the above be true in multiple expansion engines, equipped with receivers and re-heaters, the high temperatures to which the oil is subject being very conducive to carbonization. In poppet valve engines carbon formation of this nature may often cause imperfect operation of the valves.

Theory of Compounding

Where a compounded oil is used an emulsion is developed by the moisture in the steam acting with the fatty component. The lubricating film thus has a greater affinity for the cylinder walls and other wearing surfaces and becomes highly resistant to the washing action of the water in the steam. Naturally the greater the percentage of moisture in the steam the higher should be the fatty compound content of the lubricant. In general, the compound should not exceed 10 per cent, however, except in extreme cases of abnormally wet steam. We must remember that an excessive amount of fatty compound, beyond that necessary to form the requisite emulsion, will not improve the lubricating value of the oil. In fact, it may even be an objection, especially under continued exposure to high temperatures, on account of the tendency that animal fats have of decomposing under such conditions.

In regard to the proper amount of compound to use in an oil, it can be said that this should be just sufficient to maintain a film of oil on the cylinder walls. This is especially true where the exhaust steam is to be used for feed

water heating or in process work of any nature. Under such conditions it is more important than ever to observe caution in selecting the original lubricant and regulating the rate of delivery.

Present day practice is to more and more reduce the quantity of compound, and to improve its quality. That tendency in compounded oils which causes them to unite with water to form emulsions in the cylinders also prevents ready separation from water in condensed steam; furthermore, the more completely atomized the oil, the more difficulty will it have in separating from water.

Oil in the form of fine emulsions in a boiler combines with the boiler compounds to cause foaming, or with the boiler impurities to produce a coating over the tubes and fire surfaces. This coating seems to form more readily over relatively clean tubes than over dirty ones.

A very thin layer of oily sludge over a tube surface will so insulate it that there is not only a large loss in heat efficiency, but the rise in temperature of the metal may be so excessive as to cause burned out tubes or explosion of the boiler.

Types of Lubricants

To meet the average requirements effectively it has been determined that steam cylinder oils must be of comparatively heavy body and have a particularly adhesive characteristic in order to insure the maintenance of a lubricating film which will resist the wearing or scraping effects of the average valve and piston, and washing off by the steam itself.

Viscosity or body is attainable by suitable refining; adhesiveness by judicious treatment of the so-called cylinder stock by the addition of certain fixed or fatty animal oils.

Steam the Actual Lubricator

The most efficient way of getting the lubricating oil to all desired points is to make use of the steam itself, which reaches all moving elements inside of the valve chambers and cylinders with the possible exception of parts of certain types of Corliss valves.

If the oil is divided into minute globules and intimately mixed with the steam, only a very small quantity is required, and the degree of success in the atomization of the oil will control both the efficiency of lubrication of the parts and the quantity necessary.

The more complete the atomization and the more thoroughly saturated all portions of the steam, the better will be the lubrication of all the cylinder parts, and the more economical will be the consumption of oil.

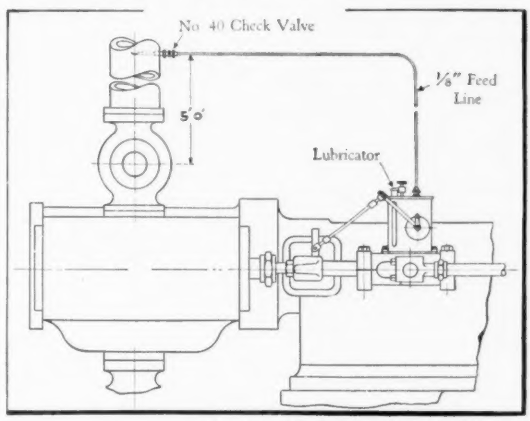
The degree of atomization of the oil is influenced by the condition of the steam, the point of introduction of the oil, the velocity of the steam, and the character of the oil itself.

High Pressure Promotes Atomization

Other things being equal, a high steam pressure will produce quicker atomization of a given oil than a low steam pressure, due to the high temperature thinning down the oil to a greater extent, so that a comparatively heavy bodied oil may be atomized by a high pressure steam as quickly as a light bodied oil will be atomized by a low pressure steam.

In general, a low pressure steam requires a light bodied oil in order to secure efficient atomization. Furthermore, a filtered oil will atomize more readily than an unfiltered product. Also, compounding with animal oils will tend to improve the atomizing ability of the average cylinder stock.

The degree of atomization is also affected by the point of introduction of the oil into the steam, in that the farther the point of introduction is from the cylinder, the greater will be the opportunity for complete atomization.



Courtesy of S. F. Bowser and Company, Inc.

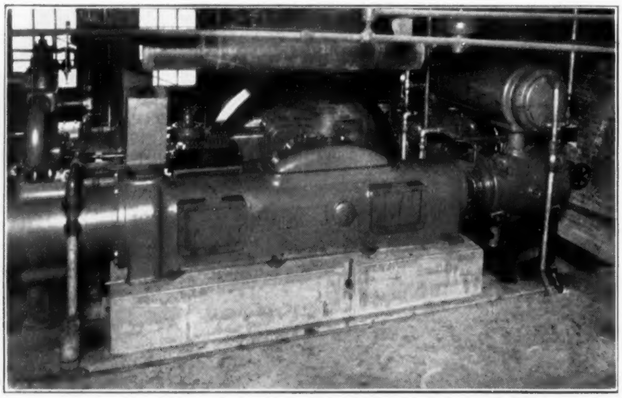
Fig. 4—Line sketch of a steam cylinder lubricator installation, showing essential dimensions, method of lubricator drive, and manner of insertion of oil atomizer.

METHODS OF APPLICATION

Application of steam cylinder oil is accomplished either by leading it directly to each of the separate wearing surfaces, or feeding it into the steam line between the throttle valve and the steam chest, the steam serving to atomize it and carry it to all moving parts within the valve chest and cylinder.

Direct application of steam cylinder lubricants by means of individual oilers installed on the valve chest and cylinder is the more crude and uncertain of the two methods, even though it involves measured lubrication. In this case the lubricant is fed drop by drop into the engine, being spread over the wearing surfaces by the movement of the valve and piston. Valve, pis-

ton and tail rod glands are often similarly equipped with drop feed oilers. While such a method of lubrication is probably not objectionable in the case of a single cylinder engine, it would be decidedly cumbersome and unreliable if applied to a multiple cylinder unit. In fact, there would be so many points requiring attention that the possibility of lack of lubrication would be very great.



Courtesy of Ingersoll-Rand Company

Fig. 5—Showing the mounting of a mechanical force-feed lubricator on a horizontal air compressor.

For this reason, steam cylinder lubrication by means of injecting oil into the steam line, using a mechanical force feed lubricator, is regarded as far more dependable and conducive to increased efficiency.

The fact that the steam in its passage through the engine reaches practically all of the surfaces requiring lubrication, insures the transmission of the particles of oil which it carries to these parts. However, sufficient oil must be fed to the steam line and the point of introduction of the lubricant must be located at a suitable distance beyond the throttle valve and the steam chest to enable the steam completely to exercise its atomizing effect.

Oftentimes this is spoken of as "lubricating the steam." Complete atomization is the secret of steam cylinder lubrication. If any of the oil is carried into the cylinder in liquid state its lubricating effect is lost, as it will either be swept out prematurely by the rush of exhaust steam or not be able to distribute itself uniformly over the wearing surfaces.

Point of Introduction

The point of introduction is, therefore, of the utmost concern. In general, if this is located at a distance of from five to eight feet above or preceding the throttle valve, unless abnormal conditions arise, atomization can be depended upon to be complete by the time the lubricated steam reaches the throttle valve, and the latter will be quite as effectively lubricated and rendered capable of as efficient operation as the working parts of the engine.

If the point of introduction is located too close to the throttle valve or cylinder, complete atomization may not take place; if too far away there will be a possibility of the oil particles being thrown to the walls of the steam line, from whence a flow of liquid lubricant will occur to the valve chest, resulting in possible waste.

In effect this might well be termed condensation of the lubricant, and it will be quite considerable if there are any bends or other pipe fittings located between the lubricator and the valve chest.

If the oil is introduced directly into the valve chest or just above the throttle, a product must be used which will break up very quickly. On the other hand, if the point of introduction is from six to eight feet from the cylinder, as stated above, it is possible to use a slower acting oil if other conditions render it necessary or advisable.

Further, if it is found necessary to use a heavy bodied oil to meet the cylinder conditions, better lubrication may be secured at a more economical cost by placing the introduction of the oil further back from the cylinder. In extreme cases it may be necessary to install auxiliary direct-feed lubricators upon the valve chest or cylinder, even though a waste of oil will be probable.

Method of Atomization

Inasmuch as the average lubricator merely serves to feed the oil into the steam line, it is necessary to install a suitable atomizer which will insure effective breaking up of the oil before it enters the steam chest and cylinders.

Atomizers are only effective, however, provided that they are properly designed and installed. Erroneous construction or careless installation may frequently defeat any possibility of satisfactory lubrication, and oil will be consumed in a relatively useless manner due to the fact that little if any of it is able to reach the valve seats or cylinder walls in suitable condition to function properly.

Care should always be taken to place the atomizer so that there are as few bends between it and the cylinder as possible, as the steam, as already stated, in striking the pipe at any bend, will throw out some of the oil onto the pipe where it may stick and run down the side.

If a steam separator is installed the oil should always be fed between the separator and the engine, otherwise the separator will remove a considerable part of the oil. Better

atomization of any oil can be secured by feeding very small drops at frequent intervals than by feeding large drops at long intervals.

Practical experience and many tests have demonstrated the soundness of the atomization theory, and the fact that most efficient results can be secured in this way.

While a considerable amount of oil which is carried by the steam never comes in contact with the metal surfaces, nevertheless, it is very evident that far less oil will be wasted when it is completely atomized than when it is introduced directly into the cylinder or valves.

The primary consideration is, of course, the efficient lubrication of the cylinders, and the oil should be selected with this in view. Then, if the point of introduction is not right to handle the oil selected, and if the mechanical conditions will permit, it should be changed to enable subsequent atomization to as complete a degree as possible.

Many times, however, it is not feasible to locate the introduction pipe at the correct point, and it becomes necessary to compromise by changing the character of the oil or by increasing the amount used.

There are two broad types of atomizers which can be used in steam power plant service. Essentially each comprises a short length of pipe or a nipple inserted in the steam pipe, its outer end being connected to the lubricator delivery pipe.

The Spoon Atomizer

This is simply a piece of pipe or nipple of the same size as the lubricator discharge, and of such a length that when inserted in the steam pipe the tip will extend somewhat beyond the center line of the latter. Both ends of the nipple should be threaded; one end with a standard length thread, the other with a long enough thread to permit it to be screwed into the steam pipe as above.

The upper part of the long thread end of this nipple should be cut away on such an angle that the remaining section will have sufficient curvature to allow for the cutting of one or more slots parallel to the axis and from one to two inches long. The tip of this nipple should be bent to a spoon-shape, the slots preferably terminating at a sufficient distance from the end to insure against loss of rigidity, although many engineers prefer to cut them through to the tip with a hack-saw.

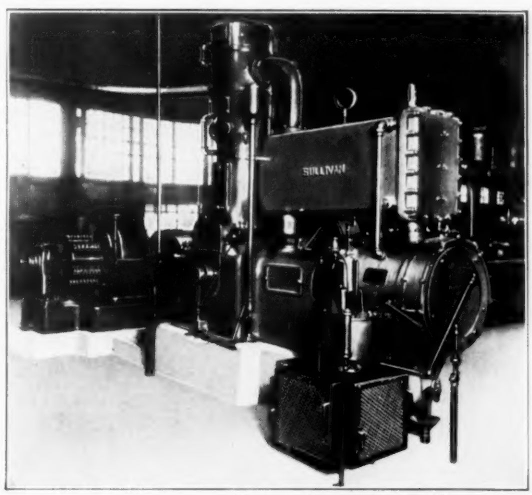
When inserting into the line, the top-side center of such an atomizer should be clearly and permanently marked for it is important that the slots be directly lined up with respect to the travel of the steam; otherwise subsequent atomization will be impaired and the steam may be unequally lubricated.

If by any chance such an atomizer is installed up-side down relatively no atomization will occur, the oil simply dripping from the nipple. It is the action of the steam, impinging on the oil as it flows out along the exposed portion of this nipple and forcing it through the slots which brings about the necessary atomization.

The Perforated Atomizer

Another type of atomizer makes use of a number of perforations in the nipple instead of slots, for the purpose of atomization. In this case, the nipple is usually not cut away, but remains intact, being drilled uniformly along the top and bottom (with respect to the axis), over perhaps a distance of two-thirds to three-quarters of the steam pipe diameter, with a sufficient number of equally spaced $\frac{1}{8}''$ to $\frac{1}{4}''$ holes. The top holes should preferably be somewhat enlarged.

The nipple may or may not be threaded over its entire length according to the way it is to be installed and attached to the lubricator fitting. Some engineers find it advisable to weld or plug up the end of this nipple which is inserted into the steam line. Others carry it through to the opposite side of the steam pipe.



Courtesy of American Air Filter Co., Inc.

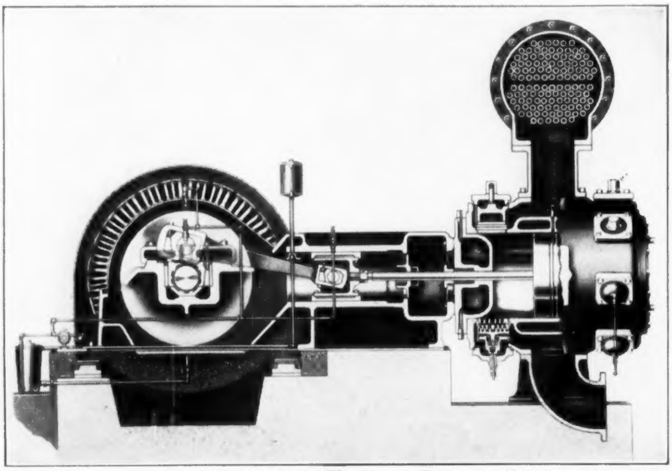
Fig. 6—The protection of lubrication in air compressor operation is as essential as controlled delivery of oil. The above shows an air filter installation on a Sullivan compressor.

This type of atomizer should be quite as carefully installed as the spoon-shaped device, and every care should be taken to see that the holes are directly in line with the direction of flow of the steam in order that the latter may blow through and carry the oil out in a spray.

If by chance such an atomizer is so installed that the perforations point towards the walls of the steam pipe, the steam may not pass through, atomization will not be effected, and the atomizer will simply become a dripping

device. Atomizers of this type are not always effective even when properly installed, due to the possibility of the holes becoming plugged up.

Another type of perforated atomizer has holes drilled in the top of the nipple only, the steam making a turn and carrying the oil out through the end. In its installation the same care should be exercised as above.



Courtesy of Worthington Pump and Machinery Corporation

Fig. 7—Sectional view of a Worthington horizontal compressor, showing oil distribution piping and means for control of oil flow.

Modified Types

Essentially, these are the only practical types of steam cylinder oil atomizers in use. Others which consist of an open ended nipple, or a nipple drawn down to an orifice, and inserted into the steam pipe so that the oil just flows out into the steam, are really dripping devices. Whether much atomization actually occurs when oil is thus allowed to drip into a volume of high velocity steam is often a question. Frequently the drops of oil will be swept to the walls of the pipe simply to run down perhaps as far as the throttle valve.

AIR COMPRESSOR SERVICE

In air compressor service measured lubrication with respect to cylinders is particularly essential in the interests of carbon reduction. Deposits of carbon on the valves or in the discharge lines are to a certain extent caused by decomposition of the oil, due to the fact that mineral lubricating oils, regardless of their base or nature, will decompose to volatile products and carbon residue when subjected to heated air under pressure. The extent of this decomposition, of course, depends on the length of time the oil is exposed to such heat, just as the amount of carbon depends upon the volume of oil used. It will also follow that the oil which remains in the compressor cylinder or on the discharge valves the longest will tend to develop the greatest amount of carbon.

On the other hand, analysis of numerous so-called carbon deposits have proven them to consist of quite as much dirt as carbon, the whole being held together by gummy matter from decomposed oil. For this reason an oil having a wide range of distillation, high end point, or too great a viscosity is objectionable, inasmuch as instead of vaporizing cleanly it will tend to break down, becoming sticky and collecting dirt brought in by the air. The slower the breaking down process, or the greater the volume of oil involved, the greater will be the ultimate amount of carbon residue. Careful regulation of oil flow will aid in reducing such residues.

Carbon may be formed in air compressor cylinders in a hard mass, or or it may be produced in the shape of dust, in which case the majority will pass out with the air. Where this latter occurs, however, such residues will often collect in pockets, elbows or on sharp edges and become mixed with dirt taken in by the air as well as with oil which has been vaporized in the cylinder, and later condensed at these points.

If deposited in the cylinder, carbon, being a poor conductor, may become heated considerably above the temperature of the cylinder walls; but whether it can become sufficiently heated to ignite or not is still a matter of dispute. However that may be, carbon is always a nuisance, and many times it accumulates on the valves and valve seats, and is packed firmly into the ends of the cylinders, causing the valves to leak and sometimes resulting in the breaking of the valves and scoring of the cylinders. Cases have been found where carbon deposits have collected in the valve passages and bends of piping to such an extent as to restrict the opening through which the compressed air had to pass. When once started, such formations continue to build up, so narrowing the passages that pressures may be produced capable of eventually causing failure.

The degree of refinement of an oil will be largely indicative of its carbon forming tendencies. Filtered oils will often show less tendency to break down to form carbon residue, or develop gummy matter. This latter is extremely important, for such gummy matter will absorb dust or dirt from the air and tend to increase the amount of residue. Furthermore, any such direct carbon that may be

formed through excessive use of highly refined oils of the proper base, is of a light fluffy nature. Any oil, however, will accumulate dust if the air is dirty.

Fixed Oil Compounds and Blended Oils

Whether or not the use of fixed oils of animal or vegetable matter such as lard oil, etc., in compound with mineral products, is advantageous for air cylinder lubrication is a subject of frequent discussion today. Where moisture is present in the air to a sufficient extent to cause appreciable precipitation of water, or if it is impossible to dry the air completely prior to its entry into the compressor (especially where higher pressures are involved), certain authorities deem it advisable to add a small amount of compound to the mineral compressor oil, or use a specially prepared product instead of increasing the rate of oil feed, in order to eliminate the possibility of dry pistons and cylinders, with subsequent loss of compression and rusting when the machine is shut down. This is especially applicable to some types of vertical and Diesel engine compressors. The ill-effects of possibly a moderate amount of increased carbonization are overlooked by some operators if by compounding their lubricating oils they can be assured of relatively satisfactory lubrication and prevention of corrosion or wear.

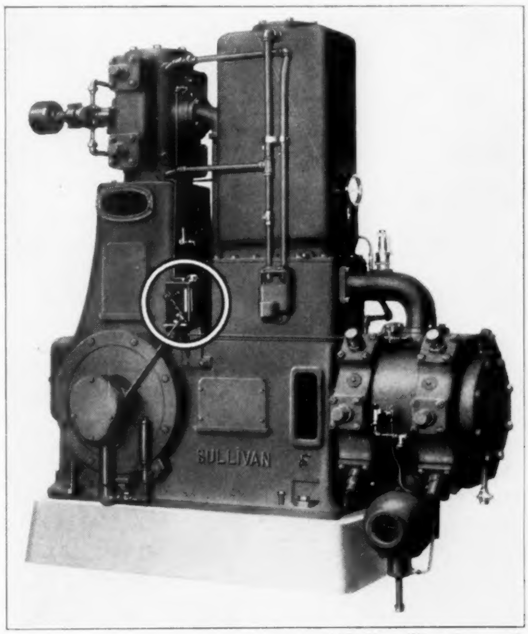
Others, however, regard the use of fixed oil compounds as a detriment, due to the fact that they are claimed to decompose slowly, especially if the mineral constituent is a blended or mixed base product. Fixed oils in fact are not subject to distillation under average conditions; instead, when exposed to higher temperatures they will tend to break down or decompose, developing a considerable amount of tarry or gummy residue.

Application of Compressor Oils

Granted that the oil to be used for air cylinder lubrication satisfies the general requirements, it is safe to state that the possibility of future difficulties due to carbon formation will depend upon the method of feeding the oil and the quantity supplied. In fact, many authorities feel that this entire matter of efficient air compressor cylinder lubrication hinges upon the amount of oil used. Any excess supplied over that actually required will mean that the oil will either be consumed by vaporization and breaking down in the compressor with the formation of a certain amount of direct carbon, or that it will be carried over with the air to collect in the intercooler or in pockets elsewhere in the system.

A compressor oil will function best when it is completely atomized prior to being delivered to the cylinder. To effect such atomization in small and medium-sized compressors, the oil is often introduced at or above the point of air intake, the inrush of air carrying the atomized particles or spray of oil to all parts requiring lubrication. On account of the lesser amount of oil involved, the lubricator can, in such cases, be located fairly near the intake as atomization is effected in a shorter distance of travel than where steam cylinders are involved.

Air, however, does not carry oil particles as readily as does steam. Horizontal compressors, therefore, may not receive sufficient oil at the uppermost parts of the piston and cylinder to insure satisfactory lubrication unless, of course, the oil feed is increased above the usual theoretical requirements. This is inadvisable, since the bottom parts of the cylinder, being probably over-lubricated, will lead to the collection of oil in pockets, with ultimate carbonization or even the possibility of explosion.



Courtesy of Madison-Kipp Corporation

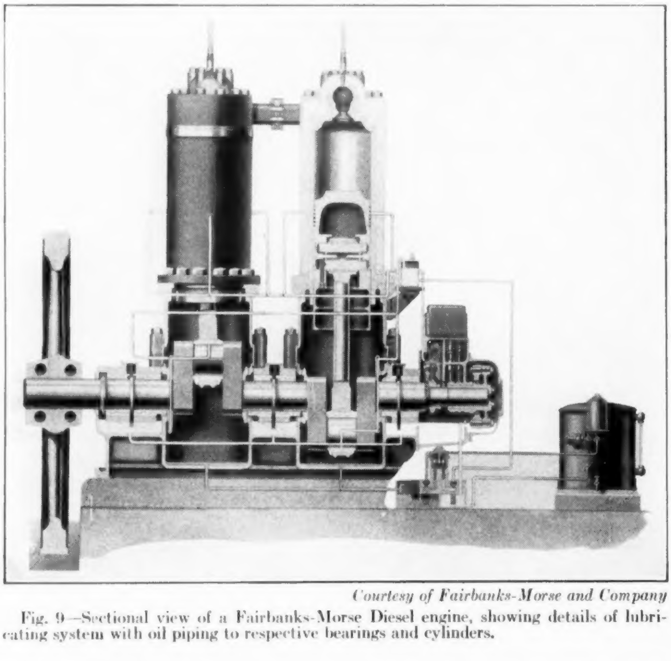
Fig. 8—View of a Sullivan angle compound compressor, showing manner of installation of a mechanical force-feed lubricator for predetermined cylinder lubrication.

In such cases the better procedure is to feed the oil directly to the sliding surfaces by means of sight feed drip oilers or mechanical force feed lubricators. This, in fact, is customary practice on all large installations. Oil introduced in this manner is distributed to the cylinder walls by the wiping action of the piston.

Automatic lubrication by means of force feed lubricators whereby the flow of oil to each part of the cylinder can be regulated is perhaps the most efficient and economical method

available. By its use, the possibility of over-feeding oil by any particular lubricator is reduced, for oil flow stops and starts with the compressor, and the requisite lubricating and sealing film is attained. Force feed lubricators are not affected by variations in air pressure, and they will feed the oil continually in accordance with their adjustments and the speed of the compressor.

Different types of compressors will naturally involve certain variations in their lubrication; in fact, they may even require radical departure from what are normally called standard methods of lubrication. In general, however, the sight feed, hand regulated, or automatic force feed lubricator can be used; the system being planned according to the recommendations of the compressor builder, based on the design of the machine, its size, capacity, and the character of the valves employed.



Courtesy of Fairbanks-Morse and Company

Fig. 9—Sectional view of a Fairbanks-Morse Diesel engine, showing details of lubricating system with oil piping to respective bearings and cylinders.

Amount of Oil Required

To attempt to establish any hard and fast rule in regard to the theoretically proper amounts of oil that should be supplied to an air compressor cylinder is never advisable. Too many variables, such as the size of the compressor, its speed, and the condition of the piston and piston walls are involved. Essentially we must guard against over-lubrication, inasmuch as more trouble will be caused by the use of too much rather than too little oil.

It must be remembered that the oil will probably remain in an air compressor cylinder considerably longer than in the cylinders of either a steam or internal combustion engine, owing to the fact that there is little or no washing action or dilution of the oil film involved. As a consequence, very much less oil will be required per unit of cylinder surface over the same time interval.

It is a safe rule to use just enough oil to prevent frictional wear and to permit easy and free operation of all parts; more than this will lead to trouble. If the lubricant is unsuitable an excessive amount will be required to keep the pistons from groaning in the cylinders; in addition, the result of using an excessive amount of oil will be carbonization in the air passages, and particularly on the discharge valves. Sticking of these valves, with the passage of hot compressed air back into the compressor cylinder, is an indication of too much oil.

The discharge valves should therefore, be examined regularly, and the aftercooler, receiver, or discharge pipes blown out. This will effectively remove any oil, water or sediment which may have accumulated. If upon removal the discharge valves have a greasy appearance, enough oil is being fed to the cylinders; on the other hand, if the parts appear very oily or little pools of oil are found in compressor pockets, or in any of the air lines, oil is being fed in excess of the amount required.

There is a general rule to the effect that air compressors are sufficiently lubricated if one or two drops of the proper grade of oil are used for each 500 or 600 square feet of cylinder surface swept by the piston per minute. This rule, on the other hand, must be governed by the condition of the cylinders, the temperature and degree of compression.

The number of drops of oil which can be secured from a certain amount of any grade of oil varies with the viscosity, temperature, service conditions involved and the diameter and shape of the lubricator orifice. Therefore, the number of drops secured per minute from an oil having a Saybolt viscosity of 200 seconds at 100 degrees Fahr. would differ from the number secured from an oil of 300 seconds viscosity. The type or design of lubricator will also affect the number of drops obtained. As a result, it is not considered good practice to make a general recommendation of the number of drops per minute that should be used in air cylinders of various sizes, on account of the great variation in operating conditions that

will be met with. In fact, two compressors of the same design, same size and built by the same manufacturer may be operating in a room under identical conditions, yet it will be practically impossible to secure the same fit of piston rings and valves and the same polished cylinder surfaces. Experience has shown that two such compressors may require a surprisingly different amount of oil for air cylinder lubrication.

In addition, the varying temperatures of the room will affect the feed of the lubricator, and while the operator may adjust the latter to give the same number of drops at different temperatures, with certain types of lubricators the difference in the size of the drops, and hence in the amount of oil fed to the cylinder, will be quite appreciable.

THE DIESEL ENGINE

In the operation of the Diesel engine the development of carbon residue will be brought about in very much the same manner as in the automotive type of internal combustion engine, in view of the comparatively high temperature to which both the lubricant and fuel are subjected. In the Diesel engine, however, there is more possibility of development of carbon residue from incomplete combustion of the fuel than in the automotive engine. The average grade of fuel oil, being very often partly or entirely of a residual nature, will have a higher percentage of certain hydrocarbon constituents, which will break down more readily and develop carbon residue.

Imperfect or incomplete combustion, therefore, requires detailed consideration, due not only to the extent to which it may develop carbon residues, but also the degree to which it may affect fuel economy in general.

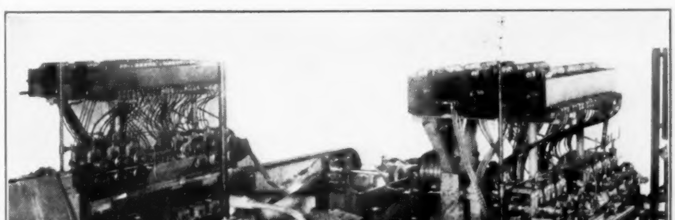
Incomplete combustion is the result of low compression pressures caused either mechanically or by leaky rings, excessive overloads or an improper mixture. Where incomplete combustion is allowed to continue carbonization will practically always occur, especially on the piston head and in all probability around the rings. Therefore, carbonization is often the cause of faulty valve action and stuck piston rings. In turn, this latter occurrence will cause compression losses.

In consequence, a complete cycle of inefficiency may result. Where rings are stuck in their grooves they must be loosened as soon as possible. Oftentimes kerosene or a lye-water mixture will serve this purpose, cutting the gummy matter effectively, in case merely scraping away the deposits is not sufficient.

Sludge Formation

In connection with the performance of lubricating oils in Diesel engine service, it is interesting to note that the development of sludge may be taken as a qualitative indication of the formation of carbon residue. This is interesting to note, in that with a knowledge of the rate of sludge separation, which can be measured by means of a centrifugal purifier, the approximate rate of carbon residue development can be judged during actual operation. Research has indicated that after an engine has been run-in, the carbonaceous sludge can be kept within 0.5 to 1.5 per cent of the volume of the oil, when this latter is continuously purified.

It is well to state, however, that the nature of the operating conditions, the rate of oil delivery, the original degree of refinement of the oil and the conditions of burning, as noted above, must be considered. Obviously, lower engine temperatures with a sufficient volume of highly refined lubricating oil to enable not too rapid circulation, can be expected to result in less sludge and carbon residue development than where the oil is subjected to high temperatures, rapid circulation and more or less oxidation.



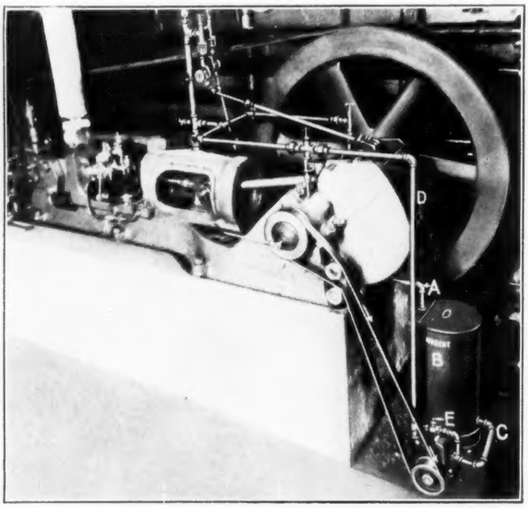
Courtesy of McCord Radiator and Manufacturing Company

Fig. 10—Showing application of a battery of six mechanical force-feed lubricators for serving the bearings on an automatic high speed tube forming machine. Controlled lubrication on this unit is of particular importance in the interests of continued production.

Diesel Compressor Service

In the Diesel engine the air compressor can be regarded as the heart of the engine, particularly due to the part it plays in bringing about combustion. It is therefore extremely important to note the effect which carbon deposits may have upon the efficiency of operation of such a compressor.

The air compressor as usually installed in higher powered Diesel engines will generally have either three or four stages, and will be equipped with suitable intercoolers. The compression of air to pressures in the neighborhood of 1,000 pounds will of course develop a con-



Courtesy of William W. Nugent and Company

Fig. 11—Indicating manner of application of the principles of controlled pressure lubrication to the bearings of a refrigerating machine. Belt drive to the oil pump is indicated by an arrow. A shows oil return line, B indicates reserve oil tank, C and E the pump connections, and D the main oil distributing line.

siderable amount of heat; it is the function of the intercoolers to reduce this heat and thereby keep cylinder temperatures down, thus minimizing the extent of oil vaporization. This is, of course, in the interests of safety, for accumulations of dust and carbonaceous matter in the intercoolers, etc., might easily so restrict the air passages as to increase the velocity and consequently the frictional temperatures of the air to a dangerous extent.

While dirty air is perhaps one of the most general causes of such accumulations of foreign matter, we must not forget that an excessive amount of lubricating oil will tend to develop carbonaceous matter which will materially increase the accumulation of deposits.

In addition, an excess of oil fed to the compressor cylinders may bring about leaky valves, due to a certain amount of oil becoming carbonized on the latter. This, of course, may lead to a decrease in operating efficiency, for this carbonaceous matter, being relatively sticky in the early stages of its formation, will also tend to adhere to the piston rings, thereby causing them to become inoperative; furthermore, it will tend to destroy the lubricating film and result in scored cylinders.

Unfortunately, there is no oil which will not deposit some carbon; on the other hand, there is a surprising difference in the nature and quantity of this carbon which will be developed by different oils. Consequently, not only must an oil be most carefully selected, but also, whatever its characteristics, the utmost care should be taken to prevent the use of more oil than is necessary.

In this respect, it is very difficult for some operators to realize that but one or two drops of oil per minute is all that is necessary. Overlubrication is effectively counteracted in many Diesel air compressors by so designing that the intermediate stage is at the bottom. As a result of such construction there is always a pressure opposing the tendency of the oil to work up into the air space from the lowest cylinder wall.

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